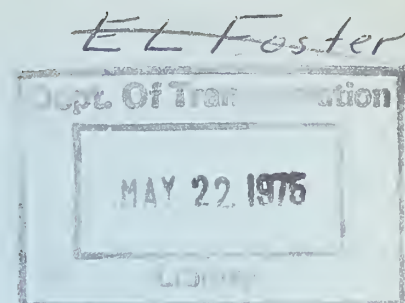


HE  
18.5  
.A37  
no.  
DOT-  
TSC-  
UMTA-  
72-5

T NO. DOT-TSC-UMTA-72-5



# REPORT ON SUBWAY TUNNELING NEEDS 13 SELECTED U.S. CITIES, 1971-75

**WILLIAM VAN DYKE  
TRANSPORTATION SYSTEMS CENTER  
55 BROADWAY  
CAMBRIDGE, MA. 02142**

**JUNE 1972  
TECHNICAL REPORT**



Approved for Urban Mass Transportation  
Administration only. Transmittal of this  
document outside must have prior  
approval of the TSC UM204 Program  
Manager.

**Prepared for:**

**DEPARTMENT OF TRANSPORTATION  
URBAN MASS TRANSPORTATION ADMINISTRATION  
WASHINGTON, D.C. 20590**

The contents of this report reflect the views of the Transportation Systems Center which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification or regulation.

MAY 22 1975

|   |  |   |           |
|---|--|---|-----------|
| 1. Report No.<br>DOT-TSC-UMTA-72-5.   | 2. Government Accession No.                          | 3. Recipient's Catalog No.  |           |
| 4. Title and Subtitle<br>REPORT ON SUBWAY TUNNELING NEEDS OF<br>13 SELECTED U.S. CITIES, 1971-75.   |  | 5. Report Date<br>June 15, 1972   |           |
|   |  | 6. Performing Organization Code   |           |
| 7. Author(s)<br>William Van Dyke  |  | 8. Performing Organization Report No.   |           |
| 9. Performing Organization Name and Address<br>Department of Transportation<br>Transportation Systems Center,<br>55 Broadway, Cambridge, Mass. 02143  |  | 10. Work Unit No.<br>R-2722   |           |
|   |  | 11. Contract or Grant No.<br>UM204  |           |
| 12. Sponsoring Agency Name and Address<br>Department of Transportation<br>Urban Mass Transportation<br>Administration<br>Washington, D.C. 20590   |  | 13. Type of Report and Period Covered<br>Technical<br>Report  |           |
|   |  | 14. Sponsoring Agency Code  |           |
| 15. Supplementary Notes   |  |   |           |
| 16. Abstract<br>This report establishes proposed subway tunneling construction needs for thirteen selected U.S. cities during 1971-75 as given by the transit authorities. This information will be used to estimate the demand for subway tunnel construction. This demand estimate is an important criterion in the generation of an UMTA R&D program in tunneling. With the knowledge of the estimated demand in dollars as a function of the various types of construction, e.g., hard rock, soft ground, cut and cover, (including a breakdown of cost by function, i.e. excavation, mucking, etc.) research requirements will be established. |  |   |           |
| 17. Key Words<br><br>Tunnels, Subway  |  | 18. Distribution Statement<br><br>Approved for Urban Mass Transportation Administration only. Transmittal of this document outside must have prior approval of the TSC UM204 Program Manager. |           |
| 19. Security Classif. (of this report)<br>Unclassified  | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>38  | 22. Price |

HE  
18.5

A37

NO.

DOT

TSC-

UMTA-

72-5

U.S.



# TABLE OF CONTENTS

|                         | <u>Page</u> |
|-------------------------|-------------|
| INTRODUCTION.....       | 1           |
| SUMMARY OF RESULTS..... | 3           |
| GLOSSARY OF TERMS.....  | 6           |
| REFERENCES.....         | 32          |



## LIST OF ILLUSTRATIONS

| <u>Figure</u>  | <u>Page</u> |
|--|-------------|
| 1. Metropolitan Atlanta Rapid Transit System.....  | 7           |
| 2. Proposed Rapid Transit Routes for St. Louis.....  | 8           |
| 3. Adopted Regional System and General Location Rapid<br>Transit Study Sections for Washington, D.C..... | 9           |





## LIST OF TABLES

| <u>Table</u>  | <u>Page</u> |
|---|-------------|
| 1. Planned Rail Rapid Transit Construction.....                       | 10          |
| 2. Summary of Planned Subway Construction.....                        | 12          |
| 3. Planned Rock Tunnel.....   | 14          |
| 4. Planned Soft Ground Tunnel.....                                    | 15          |
| 5. Planned Cut & Cover Tunnels.....                                   | 16          |
| 6. Planned Underground Stations.....                                  | 17          |
| 7. Subway Tunnel Cost by Function Cut & Cover.....                    | 19          |
| 8. Subway Tunnel Cost by Function Rock Tunnel.....                    | 20          |
| 9. Subway Tunnel Cost by Function Soft Ground Tunnel.                 | 21          |
| 10. Subway Station Cost by Function.....                              | 22          |
| 11. Transit Planning Authorities.....                                 | 23          |
| 12. Location Construction Factors.....                                | 24          |
| 13. Construction Inflation Factors U.S. 20 Cities ENR<br>Average..... | 25          |
| 14. BART Subways Average Cost per Linear Foot per<br>Track.....       | 26          |
| 15. WMATA Subway Construction Costs.....                              | 27          |
| 16. WMATA Subway Construction Costs.....                              | 28          |
| 17. WMATA Subway Construction Costs.....                              | 29          |
| 18. WMATA Subway Construction Costs.....                              | 30          |
| 19. WMATA Subway Construction Costs.....                              | 31          |



# INTRODUCTION

This report reflects the current (1971) subway tunneling requirements of 13 selected U.S. cities that are either planning a completely new rail rapid transit system or extensions to an existing system. The 13 cities have performed, as a minimum, preliminary investigations or feasibility studies on rail rapid transit systems. The data on subway tunneling demand presented here represents the instantaneous demand in 1971 and in that sense does not provide information to predict the total future demand. For instance, Detroit and Baltimore are each planning one branch of a system composed of four or five branch lines that will constitute their total integrated plan. Consequently, their future requirements for subway tunnel are not completely shown. Also, this analysis does not take into account other cities that may initiate subway construction within the next 5-15 years.

The thirteen U.S. cities surveyed for this report were:

- Atlanta
- Baltimore
- Boston
- Buffalo
- Cleveland
- Detroit
- Los Angeles
- New York
- Philadelphia
- St. Louis
- San Francisco
- Seattle
- Washington

The data was obtained from personal contacts with the transit planners in each city and from the individual engineering reports prepared for each system. The transit plans are at different stages of completion for each city. Washington and San Francisco are well into the construction phase. Los Angeles, Baltimore and Atlanta are set to begin final engineering so that they can begin construction in 1973 or 1974. St. Louis has completed the feasibility study on its proposed system, and Detroit has only completed the project definition report for a single line of subway.

The cost estimate for each system is expressed in 1970 dollars using the Engineering News Record Construction Cost Index (Tables 12 and 13). The three sources for unit cost prices are estimates by the transit planners, low bid price data from BART (Table 14) and the Washington METRO (Tables 15-19), and bid price data from tunnel construction with geological conditions similar to those found in several of the cities. The tunneling costs only include heavy construction costs, not including such items as track, electrification, train control, right of way, engineering financing and administrative costs. Likewise, the station costs include only the cost of "shell" construction and exclude architectural finish, most electrical and mechanical installations and operating equipment.

As of this time, no information has been received from New York City, so that the final results do not reflect New York's proposed subway construction.

## SUMMARY OF RESULTS

Table 1 shows a tabulation of the planned rail rapid transit construction in the 13 cities surveyed. The locations of rapid transit and tunnel construction for each city are:

Atlanta: The 56 mile transit plan, with 3.6 miles of tunnel construction along Peachtree Street in downtown Atlanta, includes four main lines extending radially from the central business district with three branch lines (Fig. 1). For additional information see Reference 1.

Baltimore: The initial plans are for two lines serving the northwest and the southern corridors of the city. The Northwest Line begins in central Baltimore and terminates at Owings Mills. The Southern Line extends from downtown to Marley with a short extension serving Friendship Airport. The 9.6 miles of tunnel run from the proposed Leadenhal Station to a point beyond Mondawmin Station. For additional information see Reference 2.

Boston: The two mile tunnel for Boston represents the contemplated extension from Harvard Square to Route 2 at Alewife Parkway.

Buffalo: The initial phase of the transit will extend northwest along the Buffalo-Amherst Corridor from downtown Buffalo to the campus of Erie Community College. The 3.9 mile tunnel segment will be constructed along Main Street in the central city. For additional information see Reference 3.

Detroit: The route will follow Woodward Avenue from downtown Detroit to the northern side of Pontiac. The tunnel portion of the route will extend from downtown Detroit, to the Eleven Mile Road Station. For additional information see Reference 4.

Los Angeles: Plans prepared by the Southern California Rapid Transit District include construction along four main corridors. The Wilshire Corridor extends from Union Station westward to MacArthur Park then along Wilshire Boulevard to its western terminus just east of the San Diego Freeway. The line will be entirely subway construction.

The San Gabriel Valley Corridor begins at the eastern terminus of the Wilshire Corridor and extends eastward in

the median of the San Bernadino Freeway to Baldwin Avenue where it leaves the expressway and continues to El Monte. The subway portion of the line is about 3/4 mile from the junction with the Wilshire Corridor to the Macy Street Yard.

The San Fernando Valley Corridor extends northeastward from its connection with the Wilshire Corridor at Wilton Place through the Santa Monica Mountains to its terminus at Tampa Avenue. The tunnel portion of this corridor consists of a 3/4 mile segment of tunnel from the intersection with the Wilshire Corridor, almost 2 miles of subway along Selma Avenue in Hollywood, and a 3 mile tunnel through the Santa Monica Mountains.

The Long Beach Corridor extends from Ninth and Broadway in Los Angeles south to its terminus in Long Beach near Long Beach Avenue. The tunnel portion consists of a 14 mile subway along Broadway and a 1 mile subway along Ocean Boulevard to the terminus in Long Beach.

For additional information see References 8, 9, and 10.

Philadelphia: The tunnel extensions to Philadelphia's subway system consist of a short extension to the South Broad Street Subway to Snyder Street and a 6.5 mile Northeast extension to the Broad Street Subway.

St. Louis: The plan has five radial lines extending from the downtown area and two circumferential lines to the west (Fig. 2). The majority of the lines will be tunnel except for the river crossings and the portions of the lines in the less densely populated areas near the suburban terminals. For additional information see Reference 13.

San Francisco: Present plans are to extend the Daly City route underground to a point just beyond the San Francisco International Airport.

Washington: The Washington Metro will extend their original 25 mile ABS route with eleven separate radial extensions. (Fig. 3). The tunnel portion of the route occurs within downtown Washington; the suburban extensions are either elevated or at grade. For additional information see References 19 and 20.

Table 2 indicates that the transit authorities contacted spend over \$3.1 billion on subway construction if the required financing is available.



Tables 3-6 give the breakdown of the major types of subway construction, e.g., rock tunnel, soft ground tunnel, cut and cover tunnel, and stations, for each city.

It is to be noted that of the 60.1 miles of planned rock tunnel, St. Louis alone accounted for 47.2 miles of this total, but the remainder of the data indicates that soft ground tunneling predominates in the metropolitan areas covered in this report.

The average cost per mile of a double track subway varies from about \$12 million in rock, about \$13 million for cut and cover construction to about \$25 million for soft ground tunnels. The cost of a 600' station (suitable for eight car trains) is about \$5 million.

Tables 7-10 show a breakdown of the type of tunnel construction by function for the entire project. It must be noted that tunnel construction is very site dependent and in a place like Washington, D.C. the site work, i.e., utilities, underpinning, dewatering, etc. can account for 25-30% of the total subway construction cost.

Table 11 lists the cities visited, the principal individual contacted, and the agency responsible for transit planning in each city. Tables 12 and 13 contain both construction cost index factors for 20 U.S. cities and construction cost inflation factors averaged for 20 cities. This information was compiled by Engineering News Record and was used to derive costs for construction projects completed at different times in different cities. For instance, in St. Louis no cost estimate was available for soft ground tunnel, so costs from San Francisco's soft ground tunneling were used, but because the San Francisco bid prices were 1966 or 1967 prices they were multiplied by the inflation factor to determine the cost in terms of 1970 prices. That price was then multiplied by the ratio of the cost indices for the two cities to arrive at an estimated cost for St. Louis.

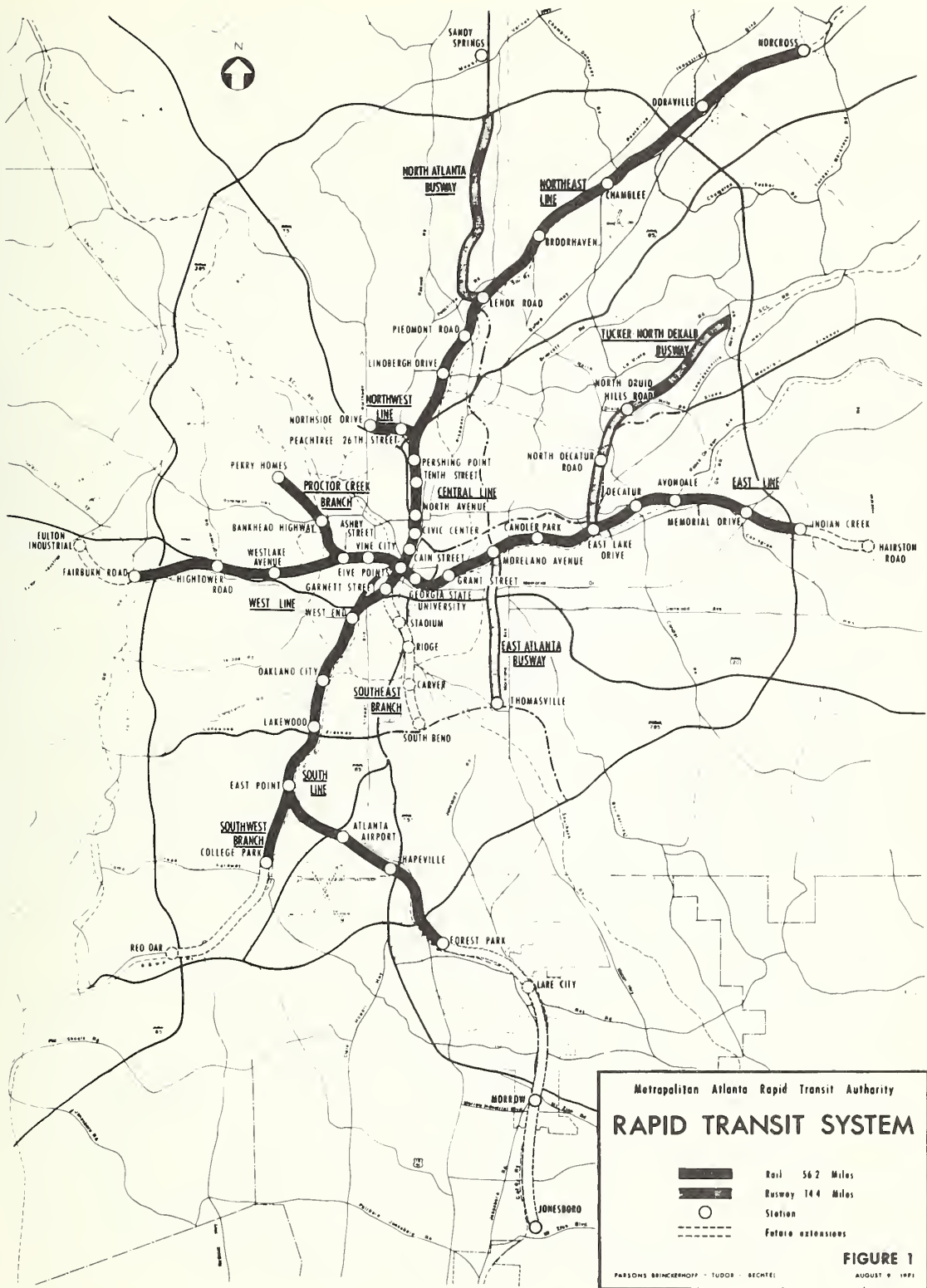
Table 14 contains a compilation of itemized bid prices from contracts for BART subway stations and subway tunnel construction.

Tables 15-19 include a cost breakdown compiled by the author from WMATA bid price data on some of their early contracts. It is to be noted that the WMATA contracts include both station and subway in a single contract, so that an item such as mobilization, utilities or adjacent structure protection may refer to the amount for that item on the entire contract.

## GLOSSARY OF TERMS

- Cut and Cover - the process of excavating a trench from the surface, building the structure, back filling, and then restoring the surface to its original condition
- Drill and Blast - A method of excavating rock tunnels with explosives using a cyclic operation of drilling, blasting and mucking
- Lining - the structure used to support both the short-term erection loads and the long-term earth loads on a tunnel
- Mechanical Excavators - refers to a variety of machines used in both soft ground and rock tunnels to disengage the material at the face of the excavation, they are commonly referred to as "moles"
- Muck - sand, clay, mud or rock that is excavated from the tunnel face and removed from the tunnel
- Rate of Advance - the rate (usually expressed in feet/day) at which the tunnel face is excavated
- Rock Tunnel - tunnel excavated in rock that requires blasting or equivalent energy to break it, where the opening can stand unsupported until permanent supports are installed
- Soft Ground Tunnel - tunnel excavated through soil in which the excavation is in immediate danger of collapse
- Supports - ground control by stabilization of the face including underpinning





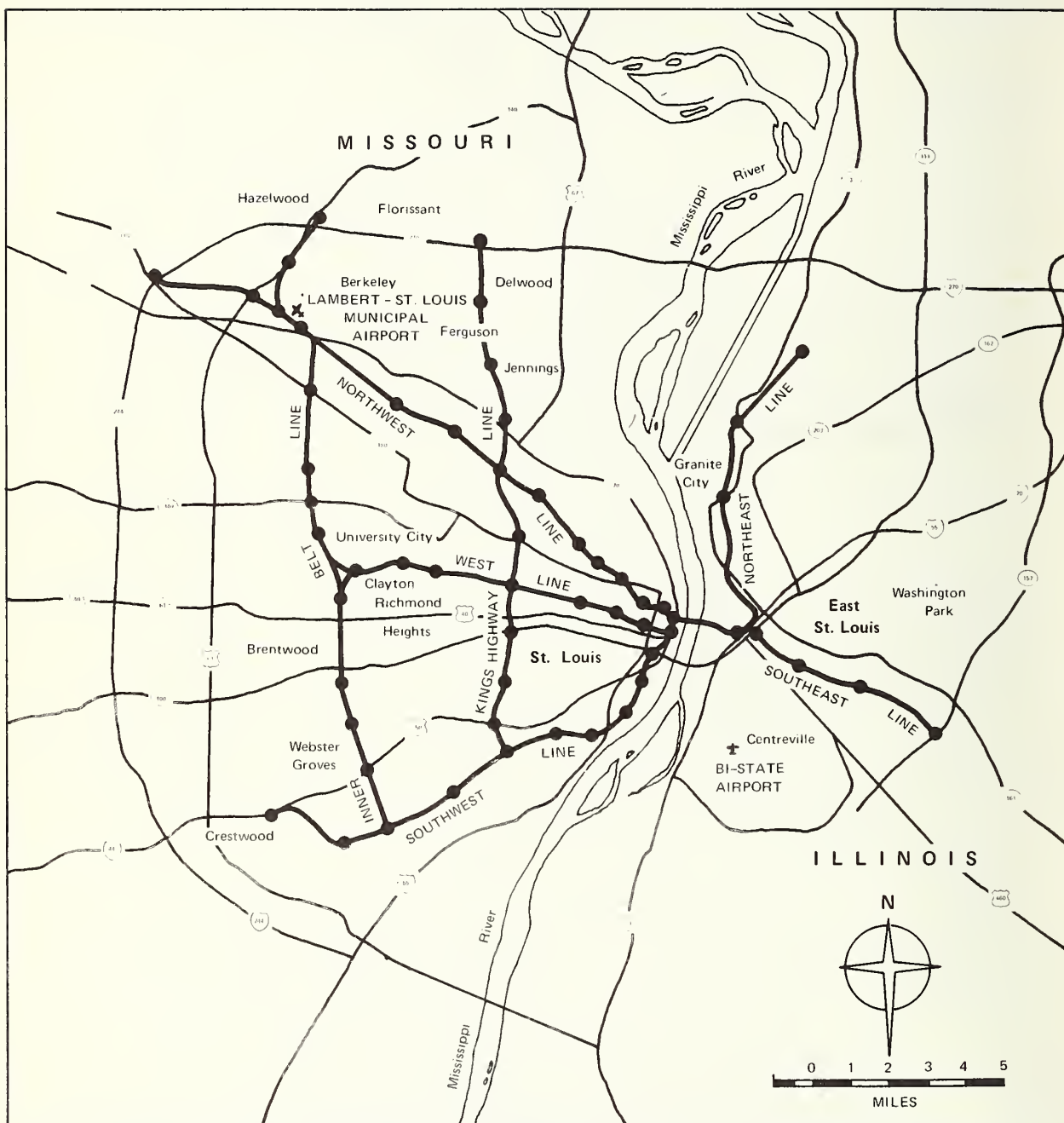


Figure 2. Proposed Rapid Transit Routes for St. Louis

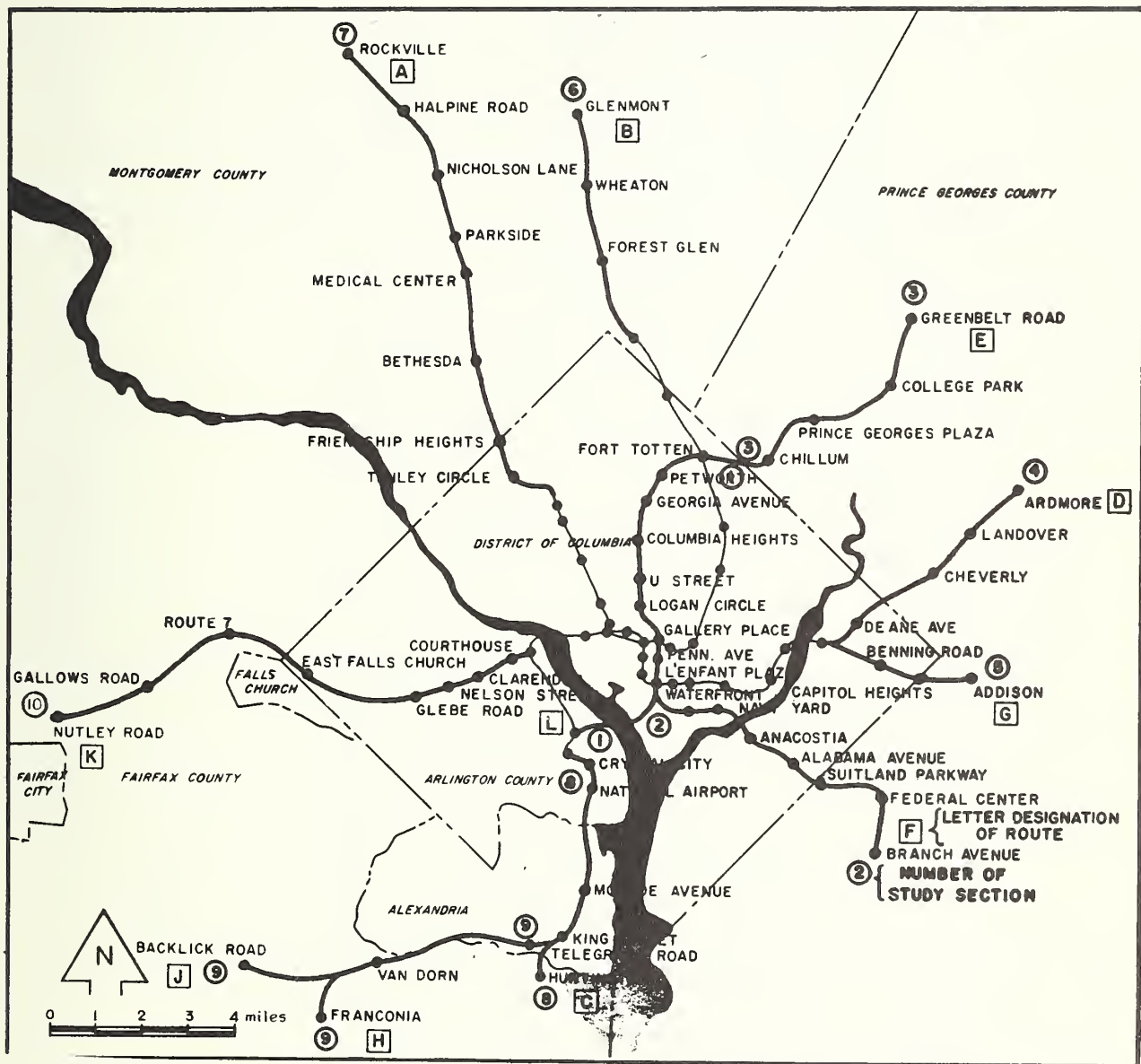


Figure 3. Adopted Regional System and General Location of Rapid Transit Study Sections for Washington, D.C.

TABLE 1. PLANNED RAIL RAPID TRANSIT CONSTRUCTION

| City        | Existing Rail Rapid Transit | Future Construction  | Future Tunnel Construction (Route miles including stations) | Anticipated Start of Construction | Remarks  |
|-------------|-----------------------------|--|---|-----------------------------------|--|
| Atlanta     | No                          | 56 mile rail rapid transit                                   | 3.6   | 1974                              | Preliminary engineering has been completed. Detailed Engineering being started.  |
| Baltimore   | No                          | 28 mile rail rapid transit                                   | 9.6   | 1974                              | Includes only Phase I plan for one transit corridor. Other possible transit corridors have been identified but preliminary engineering has not yet begun.  |
| Boston      | Yes                         | Surface extensions of existing lines with one tunnel section | 2.0   | 1974                              | Two possible routes exist for the tunnel. The tunnel section may be constructed using boring machines, but present plans call for cut and cover construction.  |
| Buffalo     | No                          | New 12.5 mile rail rapid transit                             | 3.9   | 1974                              | Preliminary engineering complete. Detailed engineering in process. 12.5 mile route is first line that will be constructed. Other routes are anticipated, but no studies have begun.  |
| Cleveland   | Yes                         | Surface extensions of existing lines                         | None  | NA                                | No definite plans are available on possible extensions.  |
| Detroit     | No                          | 25 mile rail rapid transit                                   | 10.5  | 1974                              | Project definition report completed in August, 1971 on the Woodward Avenue line. Detailed engineering studies will soon begin. Other possible transit corridors have been identified, but no current studies have begun on other possible lines. |
| Los Angeles | No                          | 89 mile rail rapid transit                                   | 22.2  | 1974                              | Preliminary engineering complete on complete 5 corridor system.  |
| New York    | Yes                         |  |   |                                   | Information not yet received.  |

NA = NOT AVAILABLE

TABLE 1. PLANNED RAIL RAPID TRANSIT CONSTRUCTION (CONTINUED)

| City          | Existing Rail Rapid Transit | Future Construction                   | Future Tunnel Construction (Route miles including stations) | Anticipated Start of Construction | Remarks  |
|---------------|-----------------------------|---------------------------------------|---|-----------------------------------|--|
| Philadelphia  | Yes                         | Several extensions of existing lines  | 9.8   | NA                                |  |
| St. Louis     | No                          | 100 mile rail rapid transit           | 68.8  | NA                                | Feasibility study on 5 transit corridors without detailed engineering analysis   |
| San Francisco | Yes                         | 10.6 mile extension to existing lines | 4.1   | NA                                | Recommended plan for possible airport extension.   |
| Seattle       | No                          | None                                  | None  | --                                | No present plans for rail rapid transit. A comprehensive rapid transit plan was completed in 1970 that included in its recommendations a 46.5 mile rail system. For the present Seattle has opted to invest transit money in upgrading their bus system. |
| Washington    | No                          | 72 mile rail rapid transit            | 32.4  | 1973                              | 72 mile Adopted Regional Lines to be added to 25 mile adopted Basic System. Presently being constructed.   |

NA = NOT AVAILABLE



TABLE 2. SUMMARY OF PLANNED SUBWAY CONSTRUCTION

| City          | Length<br>(Double Track) | Cost Estimate               |                       | Remarks<br>(Refer to Table 11)   |
|---------------|--------------------------|-----------------------------|-----------------------|--|
|               |                          | \$/LF of<br>Double<br>Track | Cost<br>\$<br>Million |  |
| Los Angeles   | 2.7 miles                | 1350                        | 19.2                  | Estimated cost from SCRTD  |
| New York      |                          |                             |                       | Information not received   |
| Philadelphia  | 0.6 miles                | 2750                        | 8.7                   | Based on BART costs  |
| St. Louis     | 47.2 miles               | 2620                        | 653.1                 | Based on 18" sewer tunnel<br>through limestone in Chicago                    |
| Washington    | 9.6 miles                | 3500                        | 177.4                 | Estimate based upon WMARTA bid<br>prices for similar construction            |
| TOTALS        | 60.1 miles               |                             | 858.4                 |  |
| Baltimore     | 3.8 miles                | 3800                        | 76.2                  | Estimate of \$15-20 million/mile<br>for tunnel by Baltimore                  |
| Detroit       | 9.2 miles                | 2000                        | 97.1                  | Estimate of \$10.5 million/mile<br>by Detroit                                |
| Los Angeles   | 16.2 miles               | 7930                        | 165.1                 | Estimate by SCRTD  |
| San Francisco | 3.7 miles                | 5100                        | 99.6                  | Estimate based on BART bid prices<br>for former work                         |
| St. Louis     | 14.1 miles               | 5100                        | 379.6                 | Estimate based on BART bid<br>prices for soft ground tunnel                  |
| Washington    | 7.6 miles                | 3250                        | 130.4                 | Estimate based upon WMARTA bid<br>prices for similar type of<br>construction |
| TOTALS        | 54.6 miles               |                             | 948.0                 |  |
| Atlanta       | 3.0 miles                | 3300                        | 52.2                  | Estimate by MARTD  |
| Baltimore     | 5.0 miles                | 3300                        | 87.1                  | Estimate by Metropolitan Transit<br>Authority                                |
| Boston        | 2.0 miles                | 2400                        | 25.3                  | Estimate based on BART cut and<br>cover bid prices                           |
| Buffalo       | 3.1 miles                | 2750                        | 45.0                  | Estimate by Niagara Frontier Transit<br>Authority                            |
| Philadelphia  | 8.9 miles                | 2400                        | 112.8                 | Estimate based on BART cut and<br>cover bid prices                           |

Subway Tunnel Costs

Rock Tunnel

Soft Ground Tunnel

Cut and Cover Tunnel

TABLE 2. SUMMARY OF PLANNED SUBWAY CONSTRUCTION (CONTINUED)

| City                 | Length<br>(Double Track) | Cost Estimate<br>\$/LF of Cost   |               | Remarks  |
|----------------------|--------------------------|----------------------------------|---------------|--|
|                      |                          | Double<br>Track                  | \$<br>Million |  |
| Washington           | 10.6 miles               | 2400                             | 134.3         | Estimate based upon BARTD bid prices for similar construction                      |
| TOTALS               | 32.6                     |                                  | 456.7         |  |
| Subway Tunnel Costs  |                          |                                  |               |  |
| Subway Station Costs | Atlanta                  | 3300 LF                          | 9.9           | Estimate by MARTD  |
|                      | Baltimore                | 4500 LF                          | 38.3          | Estimate based upon BARTD average bid prices                                       |
|                      | Buffalo                  | 4000                             | 20.6          | Estimate by NFTA   |
|                      | Detroit                  | 7200                             | 63.5          | Estimate by SEMTA  |
|                      | Los Angeles              | 17600                            | 149.5         | Estimate based on BARTD average bid prices   |
|                      | Philadelphia             | 3000                             | 22.8          | Philadelphia will build 5 subway stations. This estimate based on 600' per station |
|                      | San Francisco            | 2250                             | 19.1          | Estimate based on BARTD average bid prices   |
|                      | St. Louis                | 15600 LF<br>(rock)               | 152.8         | Estimate based upon WMATA bid prices   |
|                      |                          | 15000 LF<br>(soft ground<br>C&C) | 127.5         | Estimate based on BARTD average bid prices   |
|                      | Washington               | 6400 LF<br>(rock)                | 62.7          | Estimate based on bid prices for similar stations on WMATA                         |
|                      |                          | 18100 LF<br>(soft ground<br>C&C) | 124.9         | Estimate based on bid prices for BARTD   |
| TOTALS               | 95850                    |                                  | 791.6         |  |

TABLE 3. PLANNED ROCK TUNNEL

| City         | Length<br>(miles of dbl. trk<br>excluding stations) | Tunnel Size<br>& Configuration                     | Geological<br>Conditions  | Hydrological<br>Conditions  | Depth<br>(top of<br>rail to<br>surface)       | Probable<br>Excavation<br>Technique | Probable<br>Tunnel<br>Liner  | Remarks   |
|--------------|---|--|---|---|---|-------------------------------------|--|---|
| Los Angeles  | 2.7 miles   | 2 single track<br>tubes 16'6" in-<br>side diameter | Medium hard<br>granite and<br>sandstone   | Significant<br>seepage at<br>geological<br>fault lines            | Varies-<br>rock tun-<br>nel thru<br>mountains | Mechanical<br>excavator             | Steel ribs<br>with con-<br>crete   | Tunnel through Santa<br>Monica Mountains                                  |
| Philadelphia | 0.6 miles   | NA   | Decomposed<br>Mica<br>Schist  | Ground water<br>about 30'<br>below ground<br>surface              | 50'   | Drill &<br>Blast                    | Steel ribs<br>with poured<br>concrete  |   |
| St. Louis    | 47.2 miles  | 2 single track<br>tube 15' inside<br>diameter      | Medium hard<br>Limestone  | NA  | Generally<br>50'-70'<br>120'<br>maximum       | Mechanical<br>Excavator             | Shotcrete  |   |
| Washington   | 9.6 miles   | 2 track tunnel<br>with vertical<br>sidewalls       | Generally<br>bedrock<br>Gneiss with<br>some con-<br>struction<br>in weathered<br>rock | Ground water<br>level about<br>25' below<br>the ground<br>surface | 65' to<br>160'<br>generally<br>> 100'         | Drill &<br>Blast                    | Rock bolts<br>and shot-<br>crete in-<br>competent<br>bedrock.<br>Ribs and<br>logging<br>with<br>poured<br>concrete<br>in<br>weathered<br>rock. | Does not include tunnels<br>under construction in<br>Adopted Basic System |

NA = NOT AVAILABLE



TABLE 4. PLANNED SOFT GROUND TUNNEL

| City          | Length<br>(miles of double<br>track excluding<br>stations) | Tunnel Size &<br>Configuration                                 | Geological<br>Conditions  | Hydrological<br>Conditions   | Depth<br>(Top of<br>rail to<br>Surface) | Probable<br>Excavation<br>Technique       | Probable<br>Tunnel<br>Liner                                 | Remarks  |
|---------------|--|--|---|--|---|---|---|--|
| Baltimore     | 3.8  | 2 single track<br>tubes 16'6" in-<br>side diameter             | Silty sand<br>with some<br>decomposed<br>rock                                   | Construction<br>below ground<br>water level  | 25' to<br>100'                          | Mechanical<br>Excavator                   | Precast concrete<br>or cast iron<br>segments                |  |
| Detroit       | 9.2  | 2 single track<br>tubes 19'0" in-<br>diameter tun-<br>nel bore | Stiff homo-<br>geneous<br>clay  | NA   | NA                                      | Mechanical<br>Excavator                   | Prefabricated<br>steel<br>segments                          |  |
| Los Angeles   | 16.2   | 2 single track<br>tubes 16'6" in-<br>interior<br>diameter      | Silty,<br>clayey sand<br>with some<br>boulders                                  | Ground water<br>generally<br>< 25' from<br>surface but<br>up to 50'<br>in some<br>places | 35'-<br>70'                             | Mechanical<br>Excavator                   | Precast con-<br>crete<br>segments                           |  |
| San Francisco | 3.7  | 2 single track<br>tubes 16'6" in-<br>interior dia-<br>meter    | NA  | NA   | Approx.<br>50'                          | Mechanical<br>Excavator                   | Prefabricated<br>steel segments                             | Based on tentative route<br>to airport. No detailed<br>studies undertaken yet. |
| St. Louis     | 14.1   | 2 single track<br>tubes 15' in-<br>terior diameter             | River de-<br>posits<br>silt &<br>sand   | Ground water<br>generally 25'<br>below surface   | NA                                      | Mechanical<br>Excavator                   | NA  |  |
| Washington    | 7.6  | 2 single track<br>tubes 16'6" in-<br>interior<br>diameter      | Clayey sand<br>with some<br>gravel.<br>Some tun-<br>nel through<br>plastic clay | Ground water<br>about 20'25'<br>below surface  | 60'-<br>70'                             | Mechanical<br>Excavator<br>hand<br>mining | Steel ribs and<br>lagging with<br>cast-in-place<br>concrete | Does not include tunnel<br>under construction in<br>Adopted Basic System       |

NA = NOT AVAILABLE

TABLE 5. PLANNED CUT &amp; COVER TUNNELS

| City         | Length<br>(miles of double<br>track excluding<br>stations) | Size &<br>Configuration<br>of double<br>track   | Geological<br>Conditions  | Hydrological<br>Conditions  | Depth<br>(Top of rail<br>to surface)                    | Remarks  |
|--------------|--|---|---|---|---|--|
| Atlanta      | 3.0  | Double track<br>concrete box<br>17'X35' in-<br>terior di-<br>mensions   | Silty sand  | Ground water<br>level 25'-30'<br>below the<br>surface                 | Generally<br>35'  | Tunnel on central<br>line. This is the<br>only line with ex-<br>tensive tunnel al-<br>though other lines<br>may include short<br>portions of cut &<br>cover tunnel |
| Baltimore    | 5.0  | Double track<br>concrete box  | Sandy soil<br>with some<br>weathered<br>rock  | Construction<br>below water<br>table                                  | 25' to<br>100'  | Includes only Phase I.<br>Other possible transit<br>corridors will be<br>planned at a future<br>date.  |
| Boston       | 2.0  | Double track<br>box   | Sandy clay<br>with some<br>boulders   | NA  | Approx.<br>30'  | May change design<br>to 2-single track<br>tubes.   |
| Buffalo      | 3.1  | Double track<br>concrete box<br>13'6"X29'0"<br>interior di-<br>mensions   | Silty sand<br>& gravel  | Ground water<br>10'-20' be-<br>low the sur-<br>face                   | About 20'   |  |
| New York     |  |   |   |   |   | Information not yet<br>received.   |
| Philadelphia | 8.9  | Double track<br>concrete box<br>13'6"X30'0"<br>interior di-<br>mensions   | Clay, silty<br>clay and<br>mixed fill<br>material   | Ground water<br>15'-40' be-<br>low surface,<br>generally<br>about 30' | 30'-40'   |  |
| Washington   | 10.6   | 10.1 miles<br>double track<br>box 12'X29'<br>interior di-<br>mensions 0.5<br>miles (double<br>track)<br>single track<br>box | Clayey sand,<br>plastic clay<br>with some<br>gravel. One<br>segment<br>through<br>weathered<br>rock | Ground water<br>level about<br>25' below<br>the sur-<br>face          | Generally<br>30' to 40',<br>20' minimum<br>100' maximum | Does not include<br>tunnels under con-<br>struction for Adopted<br>Basic System  |

NA = NOT AVAILABLE

TABLE 6. PLANNED UNDERGROUND STATIONS

| City         | Configuration                         | Number | Construction Technique | Total Length (linear feet) of Double Track | Geological Conditions                | Hydrological Conditions  | Depth          | Remarks   |
|--------------|---------------------------------------|--------|------------------------|--|--------------------------------------|--|----------------|---|
| Atlanta      | Two level transfer station - 4 tracks | 1      | Cut & Cover            | 550  | Silty sand with some rock (granite)  | Ground water level 25'-30' below the surface   | About 50'      |   |
|              | Single level 2 tracks                 | 5      | Cut & Cover            | 2,750                                      | Silty sand with some rock            | Ground water level 25'-30' below the surface   | About 50'      |   |
| Baltimore    | Two level transfer station - 4 tracks | 1      | Cut & Cover            | 450  | Silty sand                           | Construction below water table   | About 50'      |   |
|              | Single level 2 tracks                 | 9      | Cut & Cover            | 4,050                                      | 1-soft clay 4-sand 4-decomposed rock | Construction below water table   | 43' to 75'     |   |
| Boston       | NA                                    | NA     | NA                     | NA   | NA                                   | NA   | NA             | Future plans may include 1 or 2 stations but plans are only in conceptual stage   |
| Buffalo      | Single level two tracks               | 8      | Cut & Cover            | 4,000                                      | Silty sand and gravel                | Ground water 10'-20' below surface   | 30'-40'        |   |
| Detroit      | Single level two tracks               | 12     | Cut & Cover            | 7,200                                      | Stiff clay                           | NA   | NA             |   |
| Los Angeles  | Single level two tracks               | 22     | Cut & Cover            | 17,600                                     | Silty clay & silty sand              | Ground water generally <25' from surface, but in some places is from 25' to 50' deep | 53'            | Consultants recommend cut & cover construction; however, transit officials may try modified construction using mining techniques with 75'x75' cut & cover opening at each end |
| New York     |                                       |        |                        |  |                                      |  |                | Information not yet available   |
| Philadelphia | Single level two tracks               | 5      | Cut & Cover            | NA   | Clay, silty clay and mixed fill      | Ground water about 30' below surface   | Varies 20'-30' |   |

NA = NOT AVAILABLE

TABLE 6. PLANNED UNDERGROUND STATIONS (CONTINUED)

| City          | Configuration              | Number | Construction Technique | Total Length (linear feet) of Double Track | Geological Conditions            | Hydrological Conditions                          | Depth       | Remarks |
|---------------|----------------------------|--------|------------------------|--|----------------------------------|--|-------------|---------|
| San Francisco | Single level<br>two tracks | 3      | Cut & Cover            | 2,400                                      | NA                               | NA   | About 40'   |         |
| St. Louis     | Double level<br>4 tracks   | 3      | Cut & Cover            | 1,800                                      | River deposits<br>Glacial till   | NA   | 50' minimum |         |
|               | Single level<br>2 tracks   | 22     | Cut & Cover            | 13,200                                     | River deposits<br>sand and silt  | NA   | 50' minimum |         |
|               | Double level<br>4 tracks   | 2      | Drill & Blast          | 1,200                                      | Medium hard<br>limestone         | NA   | varies      |         |
|               | Single level<br>2 tracks   | 24     | Drill & Blast          | 14,400                                     | Medium hard<br>limestone         | NA   | varies      |         |
| Washington    | Double level<br>4 tracks   | 3      | Cut & Cover            | 2,400                                      | Silty sand                       | Ground water level<br>about 25' below<br>surface | 50'-70'     |         |
|               | Single level<br>2 tracks   | 19     | Cut & Cover            | 15,700                                     | Silty clay<br>Clay<br>Silty sand | Ground water level<br>about 25' below<br>surface | 50'-70'     |         |
|               | Single level<br>2 tracks   | 8      | Drill & Blast          | 6,400                                      | Bedrock -<br>schistose<br>gneiss | Ground water level<br>about 25' below<br>surface | 100'-120'   |         |

NA = NOT AVAILABLE

TABLE 7. SUBWAY TUNNEL COST BY FUNCTION, CUT &amp; COVER

| CITY              | SITEWORK | MAINTENANCE<br>OF<br>TRAFFIC | UTILITIES | EXCAVATION<br>& MUCKING | BACKFILL | STRUCTURES | MECHANICAL<br>&<br>DRAINAGE | ELECTRICAL | TOTAL<br>MILL. \$ |
|-------------------|----------|------------------------------|-----------|-------------------------|----------|------------|-----------------------------|------------|-------------------|
| ATLANTA           | 4.0      | 2.2                          | 2.2       | 13.1                    | 1.4      | 27.6       | 0.5                         | 1.4        | 52.2              |
| BALTIMORE         | 6.7      | 3.7                          | 3.7       | 21.8                    | 2.3      | 46.0       | 0.8                         | 2.3        | 87.1              |
| BOSTON            | 1.9      | 1.1                          | 1.1       | 6.3                     | 0.7      | 13.4       | 0.2                         | 0.7        | 25.3              |
| BUFFALO           | 3.5      | 1.9                          | 1.9       | 11.3                    | 1.2      | 23.8       | 0.4                         | 1.2        | 45.0              |
| PHILADELPHIA      | 8.7      | 4.8                          | 4.8       | 28.2                    | 2.9      | 59.6       | 1.0                         | 2.9        | 112.8             |
| WASHINGTON        | 10.3     | 5.6                          | 5.6       | 33.6                    | 3.5      | 70.9       | 1.2                         | 3.5        | 134.3             |
| TOTAL<br>MILL. \$ | 35.1     | 19.3                         | 19.3      | 114.3                   | 12.0     | 241.3      | 4.1                         | 12.0       | 456.7             |

TABLE 8. SUBWAY TUNNEL COST BY FUNCTION, ROCK TUNNEL

| CITY              | SITWORK | EXCAVATION* | MUCKING* | LINING | STRUCTURES | MECHANICAL | ELECTRICAL | MISCEL. | TOTAL<br>MILL. \$ |
|-------------------|---------|-------------|----------|--------|------------|------------|------------|---------|-------------------|
| LOS ANGELES       | 0.7     | 6.4         | 6.4      | 4.3    | 0.4        | 0.3        | 0.2        | 0.4     | 19.2              |
| PHILADELPHIA      | 0.3     | 2.9         | 2.9      | 1.9    | 0.2        | 0.2        | 0.1        | 0.2     | 8.7               |
| ST. LOUIS         | 24.8    | 217.8       | 217.8    | 145.0  | 13.1       | 11.8       | 8.5        | 14.4    | 653.1             |
| WASHINGTON        | 6.7     | 59.1        | 59.1     | 39.4   | 3.5        | 3.2        | 2.3        | 3.9     | 177.4             |
| TOTAL<br>MILL. \$ | 32.5    | 286.2       | 286.2    | 190.6  | 17.2       | 15.5       | 11.1       | 18.9    | 858.4             |

\*Because of the many unknown site dependent constraints, the excavation and mucking function costs were arbitrarily assumed to be equal.

TABLE 9. SUBWAY TUNNEL COST BY FUNCTION, SOFT GROUND TUNNEL

| CITY              | EXCAVATION* | MUCKING* | SUPPORTS | LINING | UTILITIES | MISCEL. | TOTAL<br>MILL. \$ |
|-------------------|-------------|----------|----------|--------|-----------|---------|-------------------|
| BALTIMORE         | 22.9        | 22.9     | 6.9      | 15.2   | 1.5       | 6.9     | 76.2              |
| DETROIT           | 29.1        | 29.1     | 8.7      | 19.4   | 1.9       | 8.7     | 97.1              |
| LOS ANGELES       | 49.5        | 49.5     | 14.9     | 33.0   | 3.3       | 14.9    | 165.1             |
| SAN FRANCISCO     | 29.9        | 29.9     | 9.0      | 19.9   | 2.0       | 9.0     | 99.6              |
| ST. LOUIS         | 113.9       | 113.9    | 34.2     | 75.9   | 7.6       | 34.2    | 379.6             |
| WASHINGTON        | 39.1        | 39.1     | **11.7   | 26.1   | 2.6       | 11.7    | 130.4             |
| TOTAL<br>MILL. \$ | 284.4       | 284.4    | 85.4     | 189.5  | 18.9      | 85.4    | 948.0             |

\*Because of the many unknown site dependent constraints, the excavation and mucking function costs were arbitrarily assumed to be equal.

\*\*Does not include underpinning.

TABLE 10. SUBWAY STATION COST BY FUNCTION

| CITY              | UTILITIES | MAINTENANCE<br>OF<br>TRAFFIC | OTHER<br>SITE WORK | EXCAVATION<br>& MUCKING | BACKFILL | STRUCTURE | TUNNEL | MECHAN-<br>ICAL | ELEC-<br>TRICAL | MISCEL. | TOTAL<br>MILL. \$ |
|-------------------|-----------|------------------------------|--------------------|-------------------------|----------|-----------|--------|-----------------|-----------------|---------|-------------------|
| ATLANTA           | 1.2       | .5                           | .8                 | 2.7                     | .1       | 3.4       | .7     | .2              | .2              | .1      | 9.9               |
| BALTIMORE         | 4.8       | 1.9                          | 3.0                | 10.4                    | 0.6      | 13.2      | 2.5    | 0.7             | 0.7             | 0.4     | 38.3              |
| BUFFALO           | 2.6       | 1.0                          | 1.6                | 5.6                     | 0.3      | 7.1       | 1.3    | 0.4             | 0.4             | 0.2     | 20.6              |
| DETROIT           | 8.0       | 3.1                          | 5.1                | 17.3                    | 1.0      | 22.0      | 4.1    | 1.1             | 1.1             | 0.8     | 63.5              |
| LOS ANGELES       | 18.8      | 7.3                          | 12.0               | 40.7                    | 2.2      | 51.6      | 9.7    | 2.7             | 2.7             | 1.8     | 149.5             |
| PHILADELPHIA      | 2.9       | 1.1                          | 1.8                | 6.2                     | 0.3      | 7.9       | 1.5    | 0.4             | 0.4             | 0.3     | 22.8              |
| SAN FRANCISCO     | 2.4       | 0.9                          | 1.5                | 5.2                     | 0.3      | 6.6       | 1.2    | 0.3             | 0.3             | 0.2     | 19.1              |
| ST. LOUIS         | 35.3      | 13.7                         | 22.4               | 76.2                    | 4.2      | 96.7      | 18.2   | 5.0             | 5.0             | 3.4     | 280.3             |
| WASHINGTON        | 23.6      | 9.2                          | 15.0               | 51.0                    | 2.8      | 64.7      | 12.2   | 3.4             | 3.4             | 2.3     | 187.6             |
| TOTAL<br>MILL. \$ | 99.3      | 38.5                         | 63.2               | 214.4                   | 11.8     | 273.2     | 51.4   | 14.1            | 14.2            | 9.5     | 791.6             |



TABLE 11. TRANSIT PLANNING AUTHORITIES

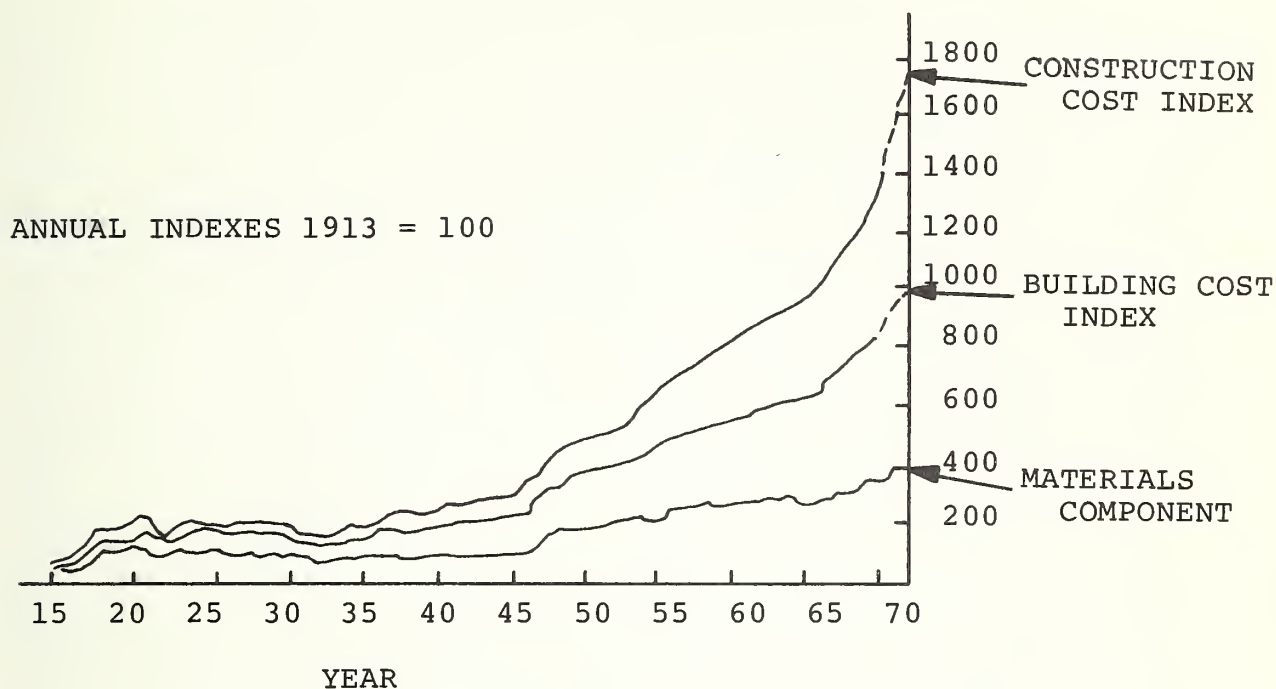
| City          | Authority and Person Contacted   |
|---------------|--|
| Atlanta       | Metropolitan Atlanta Rapid Transit District (MARTD)<br>Mr. E.W. Nelson<br>Chief Engineer (404)524-5711                       |
| Baltimore     | Mass Transit Administration (MTA)<br>Frank Hoppe (301)539-6281<br>Director of Engineering                                    |
| Boston        | Massachusetts Bay Transportation Authority (MBTA)<br>George Duarte (617)722-6187<br>Planner                                  |
| Buffalo       | Niagara Frontier Transit Authority (NFTA)<br>Gordon Thompson<br>Chief Engineer (716)842-3311                                 |
| Cleveland     | Cleveland Transit System (CTS)<br>Bert Stone (216)781-5000<br>Chief Engineer   |
| Detroit       | Southeastern Michigan Transit Authority (SEMTA)<br>David Chaffin<br>Chief Engineer (313)962-9800                             |
| Los Angeles   | Southern California Rapid Transit District (SCRTD)<br>Richard Gallagher<br>Chief Engineer (213)749-6977                      |
| New York      | New York City Transit Authority (NYCTA)<br>Eugene Casey<br>Division Engineer (212)852-5000                                   |
| Philadelphia  | Southeastern Pennsylvania Rapid Transit Authority (SEPTA) and<br>Department of Public Property<br>Robert Belfi (215)686-4496 |
| St. Louis     | Bi-State Development Agency<br>Col. R.E. Smyser<br>Executive Director (314)231-1727  |
| San Francisco | Bay Area Rapid Transit District (BARTD)<br>David Hammond<br>Chief Engineer (415)465-4100                                     |
| Seattle       | Municipality of Metropolitan Seattle (METRO)<br>William Mott<br>Transportation Planner                                       |
| Washington    | Washington Metropolitan Area Transit Authority (WMATA)<br>Vernon Garret<br>Director of Engineering (202)484-2750             |

TABLE 12. LOCATION CONSTRUCTION FACTORS

Base Index: U. S. National ENR 20 Cities Averages, September 1971

| <u>Location</u>        | <u>Construction<br/>Index</u> | <u>Building Cost<br/>Index</u> |
|------------------------|-------------------------------|--------------------------------|
| Far West               |                               |                                |
| Los Angeles            | 1.03                          | .96                            |
| San Francisco          | 1.07                          | 1.09                           |
| Seattle                | .90                           | .88                            |
| Mississippi to Rockies |                               |                                |
| Dallas                 | .78                           | .87                            |
| Denver                 | .82                           | .96                            |
| Kansas City            | 1.15                          | .98                            |
| Minneapolis            | 1.07                          | 1.01                           |
| St. Louis              | 1.13                          | .97                            |
| Middle West            |                               |                                |
| Chicago                | 1.12                          | 1.07                           |
| Cincinnati             | 1.14                          | 1.04                           |
| Cleveland              | 1.20                          | 1.13                           |
| Detroit                | 1.19                          | 1.12                           |
| South                  |                               |                                |
| Atlanta                | .76                           | .87                            |
| Birmingham             | .71                           | .81                            |
| New Orleans            | .77                           | .85                            |
| Middle Atlantic        |                               |                                |
| Baltimore              | .87                           | 1.00                           |
| New York               | 1.32                          | 1.21                           |
| Philadelphia           | .91                           | 1.03                           |
| Pittsburgh             | 1.01                          | 1.12                           |
| New England            |                               |                                |
| Boston                 | 1.05                          | 1.02                           |
| Canada                 |                               |                                |
| Montreal               | .79                           | .77                            |
| Toronto                | .85                           | .86                            |

TABLE 13. CONSTRUCTION INFLATION FACTORS  
U.S. 20 CITIES ENR AVERAGE\*



Construction Inflation Factors

U. S. 20 Cities ENR Average\*

Base 1913 = 100: Labor and Materials

|      | <u>Construction<br/>Cost Index</u> | <u>Index Using<br/>1966 Base</u> | <u>Building<br/>Cost Index</u> | <u>Index Using<br/>1966 Base</u> |
|------|------------------------------------|----------------------------------|--------------------------------|----------------------------------|
| 1966 | 1034                               | 1.00                             | 655                            | 1.00                             |
| 1967 | 1098                               | 1.06                             | 687                            | 1.05                             |
| 1968 | 1201                               | 1.17                             | 755                            | 1.15                             |
| 1969 | 1305                               | 1.26                             | 802                            | 1.23                             |
| 1970 | 1445                               | 1.40                             | 866                            | 1.32                             |
| 1971 | 1645                               | 1.59                             | 990                            | 1.51                             |
| 1972 | 1890                               | 1.83                             | 1110                           | 1.70 Est.                        |

Source: Engineering News Record, March 1971

TABLE 14. BART SUBWAYS AVERAGE COST PER LINEAR FOOT PER TRACK

|                  |                                 | 6 CUT AND COVER LINE CONTRACTS |       |        |       | 10 TUNNELED LINE CONTRACTS |        |          |       | 2 ROCK TUNNELED LINE CONTRACTS |       |          |       | 13 STATION CONTRACTS |        |          |       | TRANS BAY TUBE |       |
|------------------|---------------------------------|--------------------------------|-------|--------|-------|----------------------------|--------|----------|-------|--------------------------------|-------|----------|-------|----------------------|--------|----------|-------|----------------|-------|
|                  |                                 | MIN                            | MAX   | AVG    | AVG % | MIN                        | MAX    | AVG      | AVG % | MIN                            | MAX   | AVG      | AVG % | MIN                  | MAX    | AVG      | AVG % | COST           | %     |
| SITE WORK        | MOBILIZATION                    | —                              | \$ 72 | \$ 31  | 4.7   | \$ 40                      | \$ 365 | \$ 82    | 4.3   | \$ 18                          | \$ 44 | \$ 22    | 2.1   | \$ 135               | \$ 450 | \$ 186   | 4.8   | \$ 93          | 3.5   |
|                  | DEMOLITION AND REMOVAL          | —                              | 30    | 7      | 1.0   | —                          | 13     | 3        | 0.2   | 1                              | 1     | 1        | 0.1   | —                    | 32     | 9        | 0.2   | 49             | 1.9   |
|                  | TRAFFIC MAINTENANCE AND CONTROL | 13                             | 55    | 28     | 4.2   | —                          | 65     | 19       | 1.0   | —                              | —     | —        | —     | 13                   | 570    | 188      | 4.9   | —              | —     |
|                  | UTILITIES BY OWNER              | —                              | 39    | 11     | 1.7   | —                          | 44     | 17       | 0.8   | —                              | —     | —        | —     | —                    | 750    | 262      | 6.8   | 160            | 6.1   |
|                  | UTILITIES BY CONTRACTOR         | 8                              | 30    | 16     | 2.5   | —                          | 92     | 26       | 1.4   | 1                              | 14    | 12       | 1.2   | 30                   | 580    | 222      | 5.8   | —              | —     |
|                  | ADJACENT STRUCTURE PROTECTION   | —                              | 4     | 1      | 0.1   | 1                          | 430    | 56       | 3.0   | —                              | 6     | 1        | 0.1   | —                    | 255    | 77       | 2.0   | 2              | 0.1   |
|                  | SURFACE RESTORATION             | 5                              | 35    | 13     | 1.9   | —                          | 9      | 4        | 0.2   | —                              | 3     | 3        | 0.3   | 13                   | 82     | 40       | 1.0   | —              | —     |
|                  | SUBTOTAL                        | —                              | —     | 107    | 16.1  | —                          | —      | 207      | 10.9  | —                              | —     | 39       | 3.8   | —                    | —      | 984      | 25.5  | 304            | 11.6  |
| EARTHWORK        | SUBWAY EXCAVATION               | 55                             | 263   | 167    | 25.0  | —                          | —      | —        | —     | —                              | —     | —        | —     | 189                  | 1,920  | 1,044    | 27.2  | 297            | 11.2  |
|                  | SUBWAY BACKFILL                 | 2                              | 28    | 17     | 2.6   | —                          | —      | —        | —     | —                              | —     | —        | —     | 2                    | 102    | 56       | 1.5   | (a) 246        | 9.3   |
|                  | INSTRUMENTATION                 | —                              | —     | —      | —     | —                          | —      | —        | —     | —                              | —     | —        | —     | 2                    | 73     | 32       | 0.8   | (b) 76         | 2.9   |
|                  | SUBTOTAL                        | —                              | —     | 184    | 27.6  | —                          | —      | —        | —     | —                              | —     | —        | —     | —                    | —      | 1,132    | 29.5  | 619            | 23.4  |
| STRUCTURE        | STRUCTURAL CONCRETE             | 147                            | 269   | 204    | 30.5  | —                          | —      | —        | —     | —                              | —     | —        | —     | 185                  | 940    | 614      | 16.0  | 558            | 21.2  |
|                  | MISCELLANEOUS CONCRETE          | 3                              | 38    | 12     | 1.8   | —                          | —      | —        | —     | —                              | —     | —        | —     | 2                    | 75     | 31       | 0.8   | 18             | 0.7   |
|                  | REINFORCING STEEL               | 51                             | 90    | 69     | 10.3  | —                          | —      | —        | —     | —                              | —     | —        | —     | 100                  | 395    | 191      | 5.0   | 143            | 5.5   |
|                  | STRUCTURAL STEEL                | —                              | —     | —      | —     | —                          | —      | —        | —     | —                              | —     | —        | —     | —                    | 1,450  | 431      | 11.2  | 575            | 21.9  |
|                  | MISCELLANEOUS IRON AND STEEL    | 6                              | 16    | 9      | 1.3   | —                          | —      | —        | —     | —                              | —     | —        | —     | 15                   | 79     | 33       | 0.8   | 9              | 0.3   |
|                  | WATERPROOFING                   | —                              | 41    | 11     | 1.7   | —                          | —      | —        | —     | —                              | —     | —        | —     | 6                    | 67     | 25       | 0.7   | (c) 189        | 7.2   |
|                  | BEARING PILES                   | —                              | 91    | 13     | 2.0   | —                          | —      | —        | —     | —                              | —     | —        | —     | —                    | —      | —        | —     | (d) 39         | 1.5   |
|                  | SUBTOTAL                        | —                              | —     | 318    | 47.6  | —                          | —      | —        | —     | —                              | —     | —        | —     | —                    | —      | 1,325    | 34.5  | 1,531          | 56.3  |
| TUNNELS          | TUNNEL EXCAVATION               | FREE AIR                       |       |        |       | 247                        |        |          |       | 645                            |       |          |       | —                    |        |          |       | —              |       |
|                  |                                 | COMPRESSED AIR                 |       |        |       | —                          |        |          |       | —                              |       |          |       | —                    |        |          |       | —              |       |
|                  | LINING                          | —                              | —     | —      | —     | 139                        | 430    | 319      | 16.9  | 206                            | 332   | 228      | 22.2  | —                    | 203    | 64       | 1.7   | —              | —     |
|                  | CROSS PASSAGES                  | —                              | —     | —      | —     | 4                          | 26     | 12       | 0.6   | 6                              | 8     | 7        | 0.7   | —                    | 4      | —        | —     | —              | —     |
|                  | TERMINATIONS                    | —                              | —     | —      | —     | —                          | 38     | 12       | 0.6   | —                              | —     | —        | —     | —                    | 40     | 10       | 0.3   | —              | —     |
|                  | INVERT CONCRETE                 | —                              | —     | —      | —     | 2                          | 71     | 41       | 2.2   | —                              | —     | —        | —     | —                    | 21     | 5        | 0.1   | —              | —     |
|                  | MISCELLANEOUS IRON AND STEEL    | —                              | —     | —      | —     | 3                          | 22     | 11       | 0.6   | 1                              | 9     | 3        | 0.3   | —                    | —      | —        | —     | —              | —     |
|                  | INSTRUMENTATION                 | —                              | —     | —      | —     | —                          | 22     | 9        | 0.5   | —                              | 4     | 1        | 0.1   | —                    | —      | —        | —     | —              | —     |
|                  | SUBTOTAL                        | —                              | —     | —      | —     | —                          | —      | 1,389    | 73.4  | —                              | —     | 922      | 90.0  | —                    | —      | 251      | 6.5   | —              | —     |
| OTHER STRUCTURES | OAKLAND VENTILATION BUILDING    | —                              | —     | —      | —     | —                          | —      | —        | —     | —                              | —     | —        | —     | —                    | —      | —        | —     | 57             | 2.2   |
|                  | VENTILATION SHAFTS              | —                              | —     | —      | —     | —                          | 675    | 47       | 2.5   | —                              | 44    | 7        | 0.7   | —                    | —      | —        | —     | —              | —     |
|                  | PORTAL STRUCTURES               | —                              | 38    | 13     | 1.9   | —                          | 370    | 25       | 1.3   | —                              | 16    | 13       | 1.3   | —                    | —      | —        | —     | —              | —     |
|                  | CROSSOVERS                      | —                              | —     | —      | —     | —                          | 353    | 60       | 3.2   | —                              | —     | —        | —     | —                    | —      | —        | —     | —              | —     |
|                  | LINE STRUCTURES                 | —                              | 59    | 22     | 3.3   | —                          | 465    | 135      | 7.1   | —                              | —     | —        | —     | —                    | —      | —        | —     | —              | —     |
|                  | SUBTOTAL                        | —                              | —     | 35     | 5.2   | —                          | —      | 267      | 14.1  | —                              | —     | 20       | 2.0   | —                    | —      | —        | —     | 57             | 2.2   |
| FACILITIES       | MECHANICAL AND DRAINAGE         | 4                              | 15    | 6      | 0.9   | 3                          | 17     | 10       | 0.5   | 18                             | 27    | 19       | 1.8   | 17                   | 345    | 70       | 1.8   | 38             | 1.4   |
|                  | ELECTRICAL                      | 10                             | 28    | 17     | 2.6   | 11                         | 31     | 21       | 1.1   | 11                             | 20    | 13       | 1.3   | 20                   | 144    | 70       | 1.8   | 71             | 2.7   |
|                  | ARCHITECTURAL AND FINISH        | —                              | —     | —      | —     | —                          | —      | —        | —     | —                              | 14    | 11       | 1.1   | —                    | 122    | 15       | 0.4   | 10             | 0.4   |
|                  | SUBTOTAL                        | —                              | —     | 23     | 3.5   | —                          | —      | 31       | 1.6   | —                              | —     | 43       | 4.2   | —                    | —      | 155      | 4.0   | 119            | 4.5   |
| TOTAL            |                                 | —                              | —     | \$ 667 | 100.0 | —                          | —      | \$ 1,894 | 100.0 | —                              | —     | \$ 1,024 | 100.0 | —                    | —      | \$ 3,847 | 100.0 | \$ 2,630       | 100.0 |

(a) FOUNDATION COURSE, BACKFILL, RIP RAP PROTECTION  
(b) DIKES ENCLOSING DISPOSAL AREA.  
(c) LAUNCH, TOW, SINK, JOIN AND DEWATER JOINTS.  
(d) JOINTS

Notes: 1. Costs cover main heavy construction contracts only, excluding track, traction, electrification, train control, right-of-way, engineering, financing, and administrative costs. All costs based on low bids received.

2. "Station" contracts cover "shell" construction only, excluding architectural finish, most electrical and mechanical installations, and operating equipment.

3. Trans Bay Tube covers main tube contract, two ventilation buildings, mechanical and electrical work (excluding items listed in Note 1), and cathodic protection.

TABLE 15. WMATA SUBWAY CONSTRUCTION COSTS

| CONTRACT NO. | B002                          |                    |       | B003               |       |                             | B003    |   |
|--------------|-------------------------------|--------------------|-------|--------------------|-------|-----------------------------|---------|---|
|              | DESCRIPTION                   | Cut & Cover Tunnel |       | Cut & Cover Tunnel |       | Union Station - Cut & Cover |         |   |
|              |                               | \$1,000            | %     | \$1,000            | %     |                             | \$1,000 | % |
| Site Work    | Mobilization                  | 120.0              | 1.0   | 360.0              | 17.8  |                             |         |   |
|              | Maintenance of Traffic        | 1315.4             | 11.3  | 20.0               | 1.0   |                             |         |   |
|              | Decking                       | 1126.9             | 9.7   | 42.4               | 2.1   | 84.8                        | 2.8     |   |
|              | Utilities                     | 994.6              | 8.6   | 75.6               | 3.8   |                             |         |   |
|              | Adjacent Structure Protection | 690.3              | 6.0   | 232.1              | 11.5  |                             |         |   |
| Earth-Work   | Surface Removal & Restoration | 480.9              | 4.2   | 396.8              | 19.7  |                             |         |   |
|              | Dewatering                    | 4728.1             | 40.8  | 71.5               | 3.5   |                             |         |   |
|              | SUBTOTAL                      |                    |       | 1198.4             | 59.4  | 84.8                        | 2.8     |   |
|              | Subway Excavation             | 1189.8             | 10.3  | 76.9               | 3.8   | 283.5                       | 9.3     |   |
|              | Support of Excavation         | 2670.0             | 23.0  | 219.0              | 10.8  | 486.0                       | 15.9    |   |
| Structure    | Subway Backfill               | 667.0              | 5.8   | 68.0               | 3.4   | 124.0                       | 4.0     |   |
|              | SUBTOTAL                      | 4526.8             | 39.1  | 363.9              | 18.0  | 893.5                       | 29.2    |   |
|              | Structural Concrete           | 1722.4             | 14.9  | 342.5              | 17.0  | 1345.5                      | 43.9    |   |
|              | Miscellaneous concrete        | 579.7              | 5.0   | 83.0               | 4.1   | 47.3                        | 1.6     |   |
|              | Reinforcing Steel             |                    |       |                    |       | 523.6                       | 17.1    |   |
| Tunnel       | Structural and Misc. Steel    |                    |       |                    |       | 44.3                        | 1.4     |   |
|              | Waterproofing                 | 2302.1             | 19.9  | 5.7                | 0.3   | 68.6                        | 2.2     |   |
|              | SUBTOTAL                      |                    |       | 431.2              | 21.4  | 2029.3                      | 66.2    |   |
|              | Excavation                    |                    |       |                    |       |                             |         |   |
|              | Rock Bolts                    |                    |       |                    |       |                             |         |   |
| Facilities   | Concrete                      |                    |       |                    |       |                             |         |   |
|              | Structural Steel Supports     |                    |       |                    |       |                             |         |   |
|              | Reinforcing Steel             | 20.0               | 0.2   | 25.3               | 1.2   | 55.3                        | 1.8     |   |
|              | Miscellaneous Steel           | 20.0               | 0.2   | 25.3               | 1.2   | 55.3                        | 1.8     |   |
|              | SUBTOTAL                      |                    |       |                    |       |                             |         |   |
|              | TOTAL                         | 11,577.0           | 100.0 | 2,018.8            | 100.0 | 3,062.9                     | 100.0   |   |
|              | Length-Feet of Double Track   | 2400               |       | NA                 |       | NA                          |         |   |
|              | Bid Date                      | 3/25/70            |       | 1/25/71            |       | 1/25/71                     |         |   |
|              | Remarks                       |                    |       |                    |       |                             |         |   |

TABLE 16. WMATA SUBWAY CONSTRUCTION COSTS

| CONTRACT NO.<br>DESCRIPTION | C005                                |             |                               | C005                          |       |                 | C005            |       |
|-----------------------------|-------------------------------------|-------------|-------------------------------|-------------------------------|-------|-----------------|-----------------|-------|
|                             | Cut & Cover Subway                  |             | Rock Tunnel Single Track Tube | Rock Tunnel Single Track Tube |       | Rosslyn Station | Rosslyn Station |       |
|                             | \$1,000                             | %           |                               | \$1,000                       | %     |                 | \$1,000         | %     |
| Site Work                   | Mobilization                        | 144.7       | 5.2                           | 168.6                         | 2.1   |                 | 405.3           | 3.9   |
|                             | Maintenance of Traffic Decking      | 108.8       | 3.9                           |                               |       |                 |                 |       |
|                             | Utilities                           | 96.0        | 3.4                           |                               |       |                 |                 |       |
|                             | Adjacent Structure Protection       | 460.1       | 16.6                          |                               |       |                 |                 |       |
| Earth-Work                  | Surface Removal & Restoration       | 5.0         | 0.2                           |                               |       |                 | 13.6            | 0.1   |
|                             | Dewatering                          | 73.9        | 2.7                           |                               |       |                 |                 |       |
|                             |                                     | 40.0        | 1.4                           |                               |       |                 |                 |       |
|                             | SUBTOTAL                            | 928.5       | 33.4                          | 168.6                         | 2.1   |                 | 418.9           | 4.0   |
| Structure                   | Subway Excavation                   | 198.0       | 7.1                           |                               |       |                 | 6454.9          | 61.0  |
|                             | Support of Excavation               | 1030.0      | 37.1                          |                               |       |                 | 90.0            | 0.8   |
|                             | Subway Backfill                     | 27.0        | 1.0                           |                               |       |                 | 6544.9          | 61.8  |
|                             | SUBTOTAL                            | 1255.0      | 45.2                          |                               |       |                 |                 |       |
| Tunnel                      | Structural Concrete                 | 209.6       | 7.6                           | 3452.0                        | 42.7  |                 | 2554.5          | 24.1  |
|                             | Miscellaneous Concrete              |             |                               |                               |       |                 | 725.0           | 6.8   |
|                             | Reinforcing Steel                   | 250.0       | 9.0                           |                               |       |                 | 346.5           | 3.3   |
|                             | Structural and Misc. Steel          | 94.7        | 3.4                           |                               |       |                 |                 |       |
| Facilities                  | Waterproofing                       | 554.3       | 20.0                          | 3452.0                        | 42.7  |                 | 3626.0          | 34.2  |
|                             | SUBTOTAL                            |             |                               |                               |       |                 |                 |       |
|                             | Excavation                          |             |                               | 472.1                         | 5.8   |                 |                 |       |
|                             | Rock Bolts                          |             |                               | 2760.4                        | 34.2  |                 |                 |       |
| Facilities                  | Concrete                            |             |                               | 42.9                          | 0.5   |                 |                 |       |
|                             | Grouting                            |             |                               | 917.5                         | 11.4  |                 |                 |       |
|                             | Structural Steel Supports & Lagging |             |                               | 100.0                         | 1.2   |                 |                 |       |
|                             | Reinforcing Steel                   |             |                               | 152.5                         | 1.9   |                 |                 |       |
| Facilities                  | Miscellaneous Steel                 |             |                               | 4445.4                        | 55.0  |                 |                 |       |
|                             | SUBTOTAL                            |             |                               |                               |       |                 |                 |       |
|                             | Mechanical and Drainage             | 40.0        | 1.4                           | 20.0                          | 0.2   |                 |                 |       |
|                             | Electrical                          |             |                               |                               |       |                 |                 |       |
| Facilities                  | Architectural and Finish            |             |                               | 20.0                          | 0.2   |                 |                 |       |
|                             | SUBTOTAL                            | 40.0        | 1.4                           |                               |       |                 |                 |       |
|                             | TOTAL                               | 2777.8      | 100.0                         | 8086.0                        | 100.0 |                 | 10,589.8        | 100.0 |
| Remarks                     | Length-Feet of Double Track         | 200         |                               | 3689                          |       |                 | 6/9/71          |       |
|                             | Bid Date                            | 6/9/71      |                               | 6/9/71                        |       |                 |                 |       |
|                             | Remarks                             |             |                               |                               |       |                 |                 |       |
|                             | Excludes rock tunnel turnout        | \$1,519,700 |                               |                               |       |                 |                 |       |



TABLE 17. WMATA SUBWAY CONSTRUCTION COSTS

|            | CONTRACT NO.                         | C003               |       | C003                             |       |
|------------|--------------------------------------|--------------------|-------|----------------------------------|-------|
|            | DESCRIPTION                          | Cut & Cover Subway |       | Foggy Bottom Station Cut & Cover |       |
|            |                                      | \$1,000            | %     | \$1,000                          | %     |
| Site Work  | Mobilization                         | 450.0              | 2.8   |                                  |       |
|            | Maintenance of Traffic               | 300.0              | 1.8   |                                  |       |
|            | Decking                              | 1000.0             | 6.1   | 600.0                            | 6.6   |
|            | Utilities                            | 1930.2             | 11.9  |                                  |       |
|            | Adjacent Structure Protection        | 1150.0             | 7.1   |                                  |       |
|            | Surface Removal & Restoration        | 663.6              | 4.1   |                                  |       |
|            | Dewatering                           | 266.0              | 1.6   | 150.0                            | 1.6   |
|            | SUBTOTAL                             | 5759.8             | 35.4  | 750.0                            | 8.2   |
| Earth-work | Subway Excavation                    | 1669.4             | 10.3  | 1697.2                           | 18.5  |
|            | Support of Excavation                | 2755.0             | 16.9  | 2000.0                           | 21.9  |
|            | Subway Backfill                      | 743.5              | 4.6   | 404.0                            | 4.4   |
|            | SUBTOTAL                             | 5167.9             | 31.8  | 4101.2                           | 44.8  |
| Structure  | Structural Concrete                  | 4661.3             | 28.6  | 2907.0                           | 31.8  |
|            | Miscellaneous Concrete               |                    |       | 176.0                            | 1.9   |
|            | Reinforcing Steel                    | 628.6              | 3.9   | 757.3                            | 8.3   |
|            | Structural and Misc. Steel           |                    |       | 192.9                            | 2.1   |
|            | Waterproofing                        | 56.6               | 0.3   | 158.7                            | 1.7   |
|            | SUBTOTAL                             | 5346.5             | 32.8  | 4191.9                           | 45.8  |
| Tunnel     | Excavation                           |                    |       |                                  |       |
|            | Rock Bolts                           |                    |       |                                  |       |
|            | Concrete                             |                    |       |                                  |       |
|            | Grouting                             |                    |       |                                  |       |
|            | Structural Steel Supports            |                    |       |                                  |       |
|            | Reinforcing Steel                    |                    |       |                                  |       |
|            | Miscellaneous Steel                  |                    |       |                                  |       |
|            | SUBTOTAL                             |                    |       |                                  |       |
| Facilities | Mechanical and Drainage              |                    |       | 60.0                             | 0.7   |
|            | Electrical                           |                    |       |                                  |       |
|            | Architectural and Finish             |                    |       | 50.0                             | 0.5   |
|            | SUBTOTAL                             |                    |       | 110.0                            | 1.2   |
|            | TOTAL                                | 16,274.2           | 100.0 | 9153.1                           | 100.0 |
|            | Length-Feet of Double Track Bid Date | 2106 6/2/71        |       | 770 6/2/71                       |       |
|            | Remarks                              |                    |       |                                  |       |

TABLE 18. WMATA SUBWAY CONSTRUCTION COSTS

| CONTRACT NO. | A001                          |                              | A001  |                    | A002                       |                    |
|--------------|-------------------------------|------------------------------|---|--------------------|----------------------------|--------------------|
|              | Cut & Cover Tunnel            |                              | Metro Center Station<br>2 level transfer<br>station |                    | Earth Tunnel<br>Twin Tubes |                    |
|              | \$1,000                       | %                            | \$1,000   | %                  | \$1,000                    | %                  |
| Site Work    | Mobilization                  | 450.0                        | 2.9   |                    |                            |                    |
|              | Maintenance of Traffic        | 743.9                        | 5.0   |                    |                            |                    |
|              | Decking                       | 465.8                        | 3.0   | 1436.7             | 6.7                        | 500.0              |
|              | Utilities                     | 3062.7                       | 20.0  |                    |                            |                    |
| Earth-Work   | Adjacent Structure Protection | 4941.6                       | 32.3  |                    |                            |                    |
|              | Surface Removal & Restoration | 631.7                        | 4.1   | 1042.6             | 4.8                        | 437.8              |
|              | Dewatering                    | 212.9                        | 1.4   | 2479.3             | 11.5                       | 937.8              |
|              | SUBTOTAL                      | 10,508.6                     | 68.7  |                    |                            |                    |
| Structure    | Subway Excavation             | 582.0                        | 3.8   | 2021.3             | 9.4                        |                    |
|              | Support of Excavation         | 1237.7                       | 8.1   | 3197.1             | 14.8                       |                    |
|              | Subway Backfill               | 349.8                        | 2.3   | 458.6              | 2.1                        |                    |
|              | SUBTOTAL                      | 2169.5                       | 14.2  | 5677.0             | 26.3                       |                    |
| Tunnel       | Structural Concrete           | 1822.9                       | 11.9  | 8781.5             | 40.7                       |                    |
|              | Miscellaneous Concrete        |                              |   | 314.0              | 1.4                        |                    |
|              | Reinforcing Steel             | 377.8                        | 2.5   | 3008.7             | 13.9                       |                    |
|              | Structural and Misc. Steel    |                              |   | 683.8              | 3.2                        |                    |
| Facilities   | Waterproofing                 | 224.0                        | 1.4   |                    |                            | 4.0                |
|              | SUBTOTAL                      | 2424.7                       | 15.8  | 12,788.0           | 59.2                       | 4.0                |
| Tunnel       | Excavation                    |                              |   |                    |                            | 4961.3             |
|              | Rock Bolts                    |                              |   |                    |                            |                    |
|              | Concrete                      |                              |   |                    |                            | 165.8              |
|              | Grouting                      |                              |   |                    |                            | 731.8              |
| Facilities   | Structural Steel Supports     |                              |   |                    |                            | 329.9              |
|              | Reinforcing Steel             |                              |   |                    |                            | 6188.8             |
|              | Miscellaneous Steel           |                              |   |                    |                            |                    |
|              | SUBTOTAL                      |                              |   |                    |                            | 86.8               |
| Facilities   | Mechanical and Drainage       |                              |   |                    |                            |                    |
|              | Electrical                    | 24.0                         | 0.2   | 10.0               | 0.1                        |                    |
|              | Architectural and Finish      |                              |   |                    |                            |                    |
|              | Temporary Bunkhead            | 172.2                        | 1.1   | 635.0              | 2.9                        | 2.0                |
| Facilities   | SUBTOTAL                      | 196.2                        | 1.3   | 645.0              | 3.0                        | 2.0                |
|              | TOTAL                         | 15,299.0                     | 100.0   | 21,589.3           | 100.0                      | 7132.6             |
| Facilities   | Length-Feet of Double Track   |                              |   |                    |                            |                    |
|              | Bid Date                      | 1022                         |   | 1647               |                            | 2188               |
|              | Depth                         | 6/17/70                      |   | 6/17/70            |                            | 12/2/69            |
|              | Soil Conditions               | 40-45'<br>Silty & Sandy Clay |   | Silty & Sandy Clay |                            | Silty & Sandy Clay |
| Remarks      |                               |                              |   |                    |                            |                    |



TABLE 19. WMATA SUBWAY CONSTRUCTION COSTS

| CONTRACT NO. | Description                           | A003               |       | A003                            |       | A004        |       | A004  |      |
|--------------|---------------------------------------|--------------------|-------|---------------------------------|-------|-------------|-------|---|------|
|              |                                       | Cut & Cover Tunnel |       | Farragut N. Station Cut & Cover |       | Rock Tunnel |       | DuPont Circle Station - Rock Tunnel Station |      |
|              |                                       | \$1,000            | %     | \$1,000                         | %     | \$1,000     | %     | \$1,000                                     | %    |
| Site Work    | Mobilization                          | 250.0              | 2.1   |                                 |       | 600.0       | 13.8  |   |      |
|              | Maintenance of Traffic                | 260.0              | 2.2   | 740.0                           | 7.3   | 150.0       | 3.4   |   |      |
|              | Decking                               | 605.0              | 5.1   |                                 |       |             |       | 443.0                                       | 6.9  |
|              | Utilities                             | 2108.9             | 17.6  |                                 |       | 15.0        | 0.3   |   |      |
|              | Adjacent Structure Protection         | 1100.0             | 9.2   |                                 |       |             |       | 63.1  | 1.0  |
| Earth-Work   | Surface Removal & Restoration         | 759.5              | 6.3   | 209.0                           | 2.1   | 20.0        | 0.5   |   |      |
|              | Dewatering                            | 224.7              | 1.9   |                                 |       |             |       | 506.1                                       | 7.9  |
|              | SUBTOTAL                              | 5308.1             | 44.4  | 949.0                           | 9.4   | 785.0       | 18.0  |   |      |
|              | Subway Excavation                     | 1321.7             | 11.1  | 1357.7                          | 13.5  |             |       | 251.2                                       | 3.9  |
|              | Support of Excavation                 | 785.8              | 6.6   | 2150.0                          | 21.3  |             |       | 62.9  | 1.0  |
| Structure    | Subway Backfill                       | 1650.0             | 13.8  | 463.2                           | 4.6   |             |       | 314.1                                       | 4.9  |
|              | SUBTOTAL                              | 3757.5             | 31.5  | 3970.9                          | 39.4  |             |       |   |      |
|              | Structural Concrete                   | 2398.5             | 20.1  | 2943.1                          | 29.2  |             |       | 1492.7                                      | 23.4 |
|              | Miscellaneous Concrete                |                    |       | 230.9                           | 2.3   |             |       | 1.3   | -    |
|              | Reinforcing Steel                     | 426.4              | 3.6   | 1503.8                          | 14.9  |             |       | 316.8                                       | 5.0  |
| Tunnel       | Structural and Misc. Steel            | 0.7                | -     | 351.8                           | 3.5   |             |       | 42.0  | 0.7  |
|              | Waterproofing                         | 37.7               | 0.3   | 127.0                           | 1.3   | 21.9        | 0.5   |   |      |
|              | SUBTOTAL                              | 2863.3             | 24.0  | 5156.6                          | 51.2  | 21.9        | 0.5   | 1852.8                                      | 29.1 |
|              | Excavation                            |                    |       |                                 |       | 1392.3      | 32.0  | 3303.6                                      | 51.9 |
|              | Rock Bolts                            |                    |       |                                 |       | 233.0       | 5.4   |   |      |
| Facilities   | Concrete                              |                    |       |                                 |       | 1490.1      | 34.3  |   |      |
|              | Grouting                              |                    |       |                                 |       | 79.1        | 1.8   | 384.0                                       | 6.0  |
|              | Structural Steel Supports             |                    |       |                                 |       | 158.0       | 3.6   |   |      |
|              | Reinforcing Steel                     |                    |       |                                 |       | 114.7       | 2.6   |   |      |
|              | Miscellaneous Steel                   |                    |       |                                 |       | 27.5        | 0.6   | 3687.6                                      | 57.9 |
| Facilities   | SUBTOTAL                              |                    |       |                                 |       | 3494.7      | 80.3  |   |      |
|              | Mechanical and Drainage               |                    |       |                                 |       |             |       | 10.0  | 0.2  |
|              | Electrical                            |                    |       |                                 |       | 50.0        | 1.2   |   |      |
|              | Architectural and Finish              | 17.0               | 0.1   |                                 |       |             |       |   |      |
|              | Temporary Bulkhead                    | 17.0               | 0.1   |                                 |       | 50.0        | 1.2   | 10.0  | 0.2  |
| Facilities   | SUBTOTAL                              | 11,945.9           | 100.0 | 10,076.5                        | 100.0 | 4351.6      | 100.0 | 6370.6                                      | 100  |
|              | TOTAL                                 |                    |       |                                 |       |             |       |   |      |
|              | Length-Feet of Double Track           | 1838               |       | 770                             |       | 4000        |       | 770   |      |
|              | Bid Date                              | 9/23/70            |       | 9/23/70                         |       | 5/11/71     |       | 5/11/71                                     |      |
|              | Depth (Ground Surface to Top of Rail) |                    |       |                                 |       |             |       |   |      |
|              | Soil Conditions                       |                    |       |                                 |       |             |       |   |      |
|              | Remarks                               |                    |       |                                 |       |             |       |   |      |

## REFERENCES

1. Atlanta, Metropolitan Atlanta Rapid Transit Plan, engineering report summarizing transit plan for Atlanta by Parsons, Brinckerhoff-Tudor-Bechtel, September, 1971.
2. Baltimore, Phase I Rapid Transit Plan, prepared by MTA, May, 1971.
3. Buffalo, Appendix 4 and 6 from Niagara Frontier Mass Transit Study, TEI Consulting Engineers, Inc.
4. Detroit, Woodward Rapid Transit Project Definition Report, engineering report by Louis Klander, consulting engineers, August 15, 1971.
5. Development of a U.S. Department of Transportation R&D Program Plan for Tunneling, report on potential areas for future R&D in transportation tunneling, March, 1971.
6. Fenix and Scisson, A Systems Study of Soft Ground Tunneling, U.S. Department of Transportation, May, 1970.
7. Kuesel, T.R., "Subway Construction Costs", report on tunneling costs for BARTD prepared by Parsons, Brinckerhoff-Tudor-Bechtel, April, 1970.
8. Los Angeles, Appendix A of the Final Report, appendix to the final report by Kaiser Engineers, May, 1968.
9. Los Angeles, Preliminary Foundation Investigation, soils study by LeRoy Crandall & Associates, April, 1968.
10. Los Angeles, SCRTD Final Report, transit report by Kaiser Engineers, May, 1968.
11. Mayo, Roberts, Tunneling - The State of the Art, U.S. Department of Housing and Urban Development, January, 1968.
12. RMC, Inc., Draft of report on transportation guideway costs, December 23, 1971.
13. St. Louis, Engineering report by Parsons, Brinckerhoff-Tudor-Bechtel, August, 1971.
14. Seattle, The Rapid Transit Plan for the Metropolitan Seattle Area-Technical Appendix, engineering report by DeLeuw, Cather and Company, March, 1970.

## REFERENCES (CONTINUED)

15. Tunneling Cost Analysis, report with tabulated tunnel costs, by RMC Inc. for Federal Railway Administration, Office of High Speed Ground Transportation. Report No. FRA-RT-71-73, 1971.
16. Urban Transit Development in Twenty Major Cities, Automobile Safety Foundation, March, 1968.
17. Washington, Final Report, Subsurface Investigation Volumes 1-3, soils report on Authorized Basic System by Meuser, Ruteledge, Wentworth & Johnston, December, 1967.
18. Washington, Final Report, Subsurface Investigation, Volume 4 and Appendix A, soils report on Authorized Basic System by Meuser, Ruteledge, Wentworth & Johnston.
19. Washington, Preliminary Design and Capital Costs, engineering report by DeLeuw, Cather & Co. on Added Regional Lines, February, 1968.
20. Washington, Preliminary Subsurface Investigation, preliminary soils report by Meuser, Ruteledge, Wentworth & Johnston on the Added Regional Lines, February, 1969.
21. Washington, Bid Tabulations for Contracts 1A001, 1A0021, 1A0031, 1A0043, 1A0044, 1B0021, 1B0032, 1C0031, and 1C0051.



TSC-

UMTA-

72-5

BORROW

1

1

DOT LIBRARY



00009257